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ABSTRACT

It is suggested that a reader's idea structure will affect processing of incoming information. Two aspects of the idea structure are further developed--the truth value aspect and the analytic level aspect. The idea structure can be characterized by ideas consisting of propositions which are considered to be more or less true or false (beliefs), or by ideas which consist of untested assertions. This is the truth value aspect. Further, the idea structure discriminates between different ideas, expressed as different tent to which tent to which the reader is capable of distinguishing between ideas. One empirical study investigates the relationship between 20 psychology student's beliefs before reading a text and their comprehension of it following two readings. A measurement of the readers belief structure in terms of truth values and analytic level showed that these accounted for 39% of the interindividual variation in comprehension after the first reading and 50% of the comprehension after the second reading. By adding a recall measurement, the variation accounted for in the first reading was increased to 56%. (Appendices discuss thinking, memory, and problem solving). (Author/RD)

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ON THE RELATIONSHIP BETWEEN WORLD KNOWLEDGE AND COMPREHENSION OF TEXTS

Effects of Truth Values and Analytic Level of the Belief Structure*

Waern, Y. On the relationship between world knowledge and comprehension of texts. Effects of truth values and analytic level of the belief structure. Rep. Dep. Psychol., Univer. Stockholm, 1976, No. 468. - It is suggested that a reader's idea structure will affect his processing of incoming information. Two aspects of the idea structure are further developed, i.e. the truth value aspect and the analytic level aspect. The idea structure can be characterized by ideas consisting of propositions which are considered to be more or less true or false (beliefs) or by ideas which consist of untested assertions. This is the truth value aspect. Further, the idea structure discriminates between different ideas, expressed as different sets of propositions. The analytic level refers to the extent to which the reader is capable of distinguishing between ideas. One empirical study investigates the relationship between 20 psychology students' beliefs before reading a text and their comprehension of it following two readings. A measurement of the readers' belief structure in terms of truth values and analytic level showed that these accounted for 39% of the interindividual variation in comprehension after the first reading and 50% of the comprehension after the second reading. By adding a recall measurement, the variation accounted for in the first reading was increased to 56%.

Introduction

Research working with fundamental problems in comprehension problems represent two different approaches: the artificial intelligence and the experimental approach. The knowledge about human understanding arrived at from these different approaches is not easily combined, perhaps as Moore and Newell (1974) suggested, because of the nature of the questions posed by the different approaches. The artificial intelligence workers seek fundamental mechanisms and structures, while the experimentalists study behavioral regularities under con-

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trolled experimental conditions.

The knowledge of fundamental mechanisms arrived at through experimental work is summarized by Moore and Newell (1974, p. 223) as follows: (1) The human is capable of symbolic representation and can use a great range of multiple representations, (2) humans are indeed capable of "searching" in a data systems sense, but use only limited backtracking in the face of errors, (3) humans gain access to an immense array of knowledge in a very short time, (4) humans often seem able to derive actions directly from their knowledge, i.e. much of the knowledge seems to be held in action form. At the same time, humans are capable of following plans and of making inferences.

These mechanisms reveal knowledge to be a very central entity in the comprehension process (Points 1, 3 and 4 above). For the artificial intelligence worker, the representation problem is a central one, as the kind of representation chosen determines the nature of the system. Experimental work has shown the importance of considering not only the form but also the content of the world knowledge in studying comprehension problems.

In an extensive research program Bransford and coworkers have shown that comprehension cannot be studied solely as a function of the information given (Bransford, Barclay & Franks, 1972; Bransford & Franks, 1971; Bransford & Franks, 1972; Bransford & Johnson, 1972, 1973; Bransford & McCarroll, 1974). The world knowledge enters the comprehension process at very crucial points, resulting in different comprehensions for different world knowledges.

What is missing in the work of Bransford and coworkers is a formal analysis of text and world knowledge. Other workers have come up with somewhat different suggestions (see for instance Schank, 1972; Frederiksen, 1975b; Kintsch, 1975). The common element of these suggestions lies in a description in terms of a connected graph, one difference being in the number of graphs suggested as a representation of text and/or world knowledge. Schank´s system involves only one graph, representing connections between concepts. Frederiksen uses two graphs for describing texts, one semantic, representing connections between concepts (differing, however, from Schank´s) and one logical, representing connections between propositions. Kintsch (1975) points out that the processing of a text may occur at many different, possibly parallel levels. Research results obtained by Kintsch show that the level used by the subject depends on the task. It might thus be advantageous to analyze world knowledge on different levels. The relation between world knowledge and comprehension might be different depending upon which level that is actualized in the comprehension task.

Theoretical Background

In describing the world knowledge used to comprehend different texts, different structural descriptions, working with different elements, may be used. It is suggested that these structures are hierarchically organized. Some parallel processing of the different structures probably occurs. The task given to the subject determines the general level on which he will work. This structures will then place

some restrictions upon the structural descriptions below that level. So, for instance, in working with the meaning of sentences, the wording or syntax of the sentence will be considered only in those cases where it must be used in order to disambiguate the meaning.

The level supposed to be relevant in the empirical study presented below is that corresponding to the idea in a text. The idea is regarded to have a position in a hierarchically organized set of concepts as is represented in Table 1.

Table 1. Concepts to be used in describing world knowledge in reading a text.

World knowledge (consisting of idea structures)
Idea structure (consisting of ideas)
Idea = Conceptual structure (consisting of propositions)
Propositions (consisting of concepts and relations)
Concept and relation (consisting of values placed on semantic features)

The concepts in the table are chosen to represent the data base on which different processes work to give a comprehension of the idea of a text. As is seen, no concepts referring to perceptual or syntactic processing are used. This does not imply that perceptual and syntactic processes do not occur, nor that they precede the conceptual processing. Instead, as was suggested by Greeno (1974), it is assumed that perceptual and linguistic processing do not affect the form of the cognitive structure that subjects build.

The world knowledge is regarded to contain many idea structures, having ideas as their elements. The ideas are represented by propositions, and each proposition is described in terms of concepts and relations between concepts. Finally, a single concept is characterized by values placed on a set of distinctive semantic features. Let us look somewhat more closely at each of the concepts.

Values placed on semantic features

The most elementary concept is designated as the value placed on a certain semantic feature. A semantic feature can be regarded as a dimension, on which concepts may differ, that is, assume different values. The dimension may be bi- or multivalued, discontinuous or continuous. It is assumed that the semantic features are used only in comparisons, thus it cannot be said that a single concept has a specified set of semantic features, on which its values can be characterized. Rather, the semantic features are used to compare and contrast concepts, thus evoking a different set of semantic features for each pair of concepts considered. This assumption is based upon the proposal by Olson (1970) that a semantic description must be based upon the alternatives to which the descriptions refer. Here the alternatives which restrict the semantic descriptions will be alternative propositions derived from alternative ideas in the idea structure (see below).

Concepts and relations

The terms concepts and relations are used in the description of a text in terms of a "semantic network", "knowledge structure" or "conceptual structure". Some words in the text are used as nodes in the structure; these are called concepts. The relations between the nodes can be function words or theoretical constructs. The choice of concepts and relations to describe the text varies between different descriptive systems.

Propositions

Elementary propositions, which consist of two concepts and the relation between them, can be combined to form complex propositions. The elementary proposition represents one part of the conceptual structure (i.e. a relation between two nodes).

Truth values. One property of propositions, their truth value, will be further developed here. Propositions may be regarded as more or less true (or false), or as having a neutral truth value.

World knowledge can be divided into two structural parts, a "belief" structure and an "untested assertion" structure. Propositions having some degree of truth in the person's eyes may be regarded as belonging to the former structure and propositions remaining as yet hypothetical to him to the latter. The separation of propositions into these two groups seems necessary in a theoretical analysis of the comprehension process (cf Waern, 1977).

Conceptual structure

A conceptual structure is defined by the set of its relevant elements (concepts) and the relations between them. A conceptual structure may be described as a graph, where the nodes represent concepts and the relations are labeled or unlabeled. A conceptual structure may also be described by the set of propositions which may be derived from reading the graph. The term conceptual structure as used here is equivalent to the word "idea". An idea is thus here conceived as consisting of may propositions, covering different concepts. An idea may be represented by a label (e.g., S-R) but not by a single proposition.

Idea structure

The idea structure is one whose elements consist of ideas (i.e. conceptual structures) the relations of which can be defined as "similar to", "included in", "opposite to", etc. The concept "idea structure" is introduced in order to describe the restrictive effect that ideas exert on semantic description. A person may for instance consider one idea to be true and at the same time consider the complementary idea false. The semantic description of his world knowledge must then be performed so that these two ideas either use concepts which occupy different positions in the same set of semantic features or use propositions with the same concepts but opposite relations. In the present use of the idea structure concept only the relations "included in" and "different from" will be used. By the relation "included in" ideas can be hierarchically organized, i.e. ideas may

be regarded as more or less general with respect to each other. One idea can be made more specific than another either by adding new concepts to the more general idea or by adding more semantic features to the concepts or relations defining the more general conceptual structure (idea). The relation "different from" is used to separate ideas on the same level. By adding concepts or semantic features different propositions are formed by using different values on the new features. The propositions formed by different values on the same feature are incompatible with each other but are included in the same more general idea, where these features are not used. The construction of one single specific idea thus produces an "appendage" to this idea, consisting of propositions formed by the other possible values on the chosen specific features. This appendage may or may not correspond to a conceived idea.

Analytic level. If the relation "inclusion" is used to characterize the idea structure, a given idea can be characterized by its position in the hierarchical structure of ideas. This position will be called the idea's analytic level which in turn may be defined by the sets of propositions between which the idea discriminates. Fig. 1 presents a conceptualization of the concept of idea structure, which can be used to illustrate the concept of analytic level. The label "level" on the different sets of propositions indicates that the propositions differ in terms of number of concepts and/or semantic features. The higher the level, the more concepts and/or semantic features are involved.

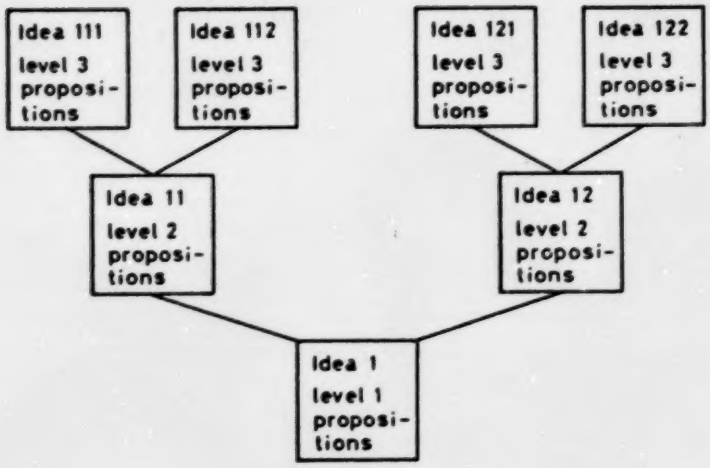

Fig. 1. A hierarchical idea structure.

The concept of analytic level can be used to characterize beliefs as well as untested assertions. Let us take as an example a person who holds the conceptual structure defining idea 11 to be true. If at the same time he regards the conceptual structure defining idea 12 to be false, his belief can be said to have an analytic level of 2. If at

the same time he recognizes that the propositions included in idea 111 do belong to the same conceptual structure, and that this set of propositions is incompatible with propositions which are derived from idea 112 the untested assertions stored in his mind can be assigned an analytic level of 3.

Comprehension as a matching task

In order to be able to say something about how world knowledge may influence comprehension, it must also be specified how the world knowledge is used. Here the task to measure comprehension will be taken as the point of departure. The task (described in more detail below) requires the reader to tell whether or not a given proposition, which is not identical to any proposition in the text, is nonetheless implied by it. It will be assumed that the subject accomplishes this task by searching through his world knowledge for a path that can link the given proposition and text, as it is comprehended. This assumption is founded upon the essence of the research results presented by Bransford and coworkers (see e.g., Bransford & McCarroll, 1974) and also by Frederiksen (1975a). These results imply that comprehension is not restricted to the exact wording of the text, but also involves inferences and generalizations, derived from the world knowledge.

In a comprehension task like the one in the present investigation the process can be analyzed in such operations as matching and searching. The task may then be accomplished in the following way. The proposition to be judged is matched against the text, whereupon the ensuing differences are utilized in the search process. If a satisfactory path is found between the proposition and the text, the matching is positive, and the subject answers that the proposition is implied in the text. If no path is found, or if a path is found indicating that the proposition and the text represent different ideas the subject will answer that the proposition is not implied in the text.

This conceptualization of comprehension in terms of a matching task opens a variety of research questions, all of which cannot be answered at once. Questions regarding the size of the text, the strategies for searching, the criterion for matching, etc. will be postponed. The present work seeks to determine the extent to which the world knowledge - through which the subject searches for a path that matches the text to the given proposition - contributes to and hinders comprehension.

The concepts of truth value of propositions and analytic level of beliefs are used as points of departure for predicting the effects of world knowledge on comprehension. The following cases will be considered: (1) the text and the reader share the same truth values and the same analytic level, (2) the text and the reader differ as to truth values but not as to analytic level, (3) the text has an analytic level higher than the reader's, (4) the text has an analytic level lower than the reader's.

All possible combinations of truth value and analytic levels have not been taken up because these two concepts are not independent. A difference in truth value need not imply a difference in analytic level. A difference in analytic level, however, cannot help but imply a dif-

ference in truth values if the analytic level is defined in terms of beliefs (i.e. propositions with some truth value). To simplify the problem, the analytic level henceforth refers to analytic level of belief if not further specified.

In the first case the easy matching task should be performed without errors. The reader would arrive rather quickly at a satisfactory matching between the given proposition and the text he has read.

The second case calls for a text presenting a belief that is incompatible with the reader's. The reader can separate his own idea from the idea of the text just as the text separates its idea from the reader's. In this case it will be difficult for the reader to construct a path between text and comprehension if the incompatible propositions contained in the text do not form a single consistent conceptual structure. As was mentioned above, the "appendage" resulting from forming an idea on a given analytic level may not correspond to a conceived idea. The reader will thus in this case arrive at some unsatisfactory matchings. How these will be resolved is a question which cannot be answered solely from knowledge of the reader's ideas. The outcome of the second case cannot therefore be predicted on the basis of the belief structure alone.

In the third case the reader will arrive at a match through a path which does not discriminate between those ideas that are discriminated by the text. This implies that the reader will match incompatible propositions to the idea presented in the text without detecting his own miscomprehension. Such a miscomprehension can be regarded as one source of the assimilation effect found in a previous study (Waern, 1976). At the same time the third case can give rise to accommodations. During the reading and matching task the reader may come to perceive that the text requires certain discriminations which he himself does not make. As the semantic features are always available, it is possible that the reader through a concept formation process reformulates his own ideas on a higher analytic level. Thus it is suggested, that both the assimilation and the accommodation effects previously found derived from the fact that the analytic level of the reader was lower than that of the text.

In the fourth case, where the reader's belief structure has a higher analytic level than the text's, the reader will be able to find a correct matching. He will probably also end up with a feeling that the text covers the problem at hand unsatisfactorily. This feeling will not be examined in the present approach.

Empirical Investigation

In the study presented here, the effect of world knowledge upon comprehension will be investigated by relating individual differences in terms of truth value and analytic level of beliefs to individual differences in terms of comprehension. Furthermore, information about other sources of differences in comprehension will be sought.

Operational definitions of the concepts involved must be developed. As the possible conclusions will refer to the operational definitions as well as to the theoretical concepts, some different approaches to empirical realization of the concepts will be tried. The operational

definitions are given below.

Operational definitions

The idea given in the text. The construction of two texts, each presenting an alternative idea in the area chosen, was considered to be the most straightforward way to define a certain idea. The texts covered the area of thinking and problem solving. One was written with an S-R-model as its point of departure, the other with a supposed alternative, a reconstructive model. (See Appendix 1 for a presentation of the texts). The idea in each of the texts was also formulated in a set of pairwise propositions, one proposition supposedly representative of an S-R-view, the other of a reconstructive view of thinking. The idea of the text was also represented by propositions formulated on a level of analysis which does not discriminate between the two theoretical standpoints. (See Appendix 2 for presentation of the propositions).

Truth value of idea. The propositions which should cover the meaning of the text were considered to have truth values of 1. Propositions which were not implied by the text were considered to have truth values of zero.

The truth values of the reader's world knowledge were determined in two different ways: (a) by having the reader estimate his degree of agreement with each proposition on a three-grade scale, 1 = agreement, 0 = no opinion, -1 = nonagreement. The propositions rated in category 1 were considered to reflect the subject's beliefs. (b) the subjects were instructed to write short essays about their own beliefs and theoretical knowledge in the area of "thinking".

Analytic level. The analytic levels of the texts were taken as points of departure. The propositions constructed were regarded to have either the same or a lower level of analysis. The analytic level of the reader's world knowledge was determined in two different ways:

(1) Analytic level of beliefs. By choosing between two alternative ideas, the level of analysis can be defined by the discrimination of these two ideas. The subject's estimations of the truth values of propositions representing each of the two chosen ideas were used to estimate the analytic level of their beliefs.

(2) Analytic level of untested assertions. Two different tasks were used in an attempt to maximize the subject's use of untested assertions. a) The subjects were instructed to sort the propositions and to combine them in different groups which he regarded as belonging together. b) The short essays mentioned above were deemed as forming another indication of the subjects' level of analyzing his own store of untested assertions as well as beliefs.

Comprehension. Comprehension was measured by giving the subjects the list of propositions and instructing them to estimate whether the author of the text would agree with, or disagree with each proposition in turn, or whether it was impossible to derive the author's view from the text.

Memory. As much of the comprehension research has been based upon some measure of the subjects' memory of the presented material, a memory measurement was also included. The subjects were instructed to reproduce the content of the text in their own words, i.e. a free recall task.

Method

Material. Two different texts were used having the same heading: "On thinking, memory and problem solving". The texts were constructed in as parallel a fashion as possible, giving an S-R-theoretical and a reconstructive theoretical formulation respectively of thinking and problem solving. The texts are given in full in Appendix 1. The propositions to be used in the comprehension measurement were constructed to cover six different areas, to which the idea given in the texts could be applied. Within each area, five different propositions were constructed: two parallel ones, S-R and reconstructive, respectively, for each of the ideas, and a "filler" proposition, formulated on an analytic level, where discrimination between the two ideas was impossible. The propositions are found in Appendix 2, organized as to area and idea.

Subjects. Twenty psychology students served as subjects. They were volunteers, but participation in a certain number of investigations was a course requirement. Ten subjects read the S-R-text, ten the reconstructive.

Procedure. The study involved two sessions.

Session 1 aimed at getting a picture of the subjects' ideas about the area involved before presenting a text. This was performed in the following way:

(1) First the subjects received the list of propositions and were instructed to indicate whether they agreed with, disagreed with or had no opinion with respect to each proposition.

(2) The subjects were given each proposition on a separate paper and were asked to sort the propositions according to the basic idea about thinking each represented. The subjects were allowed to construct as many piles (categories) as they wanted to and had no time limit.

(3) The subjects were asked to write a brief essay about their own ideas on "thinking" and about their knowledge of different theoretical perspectives with respect to "thinking".

The second session, which took place 1 - 3 weeks after the first, had the following content:

(1) The subjects were instructed to read the text in such a manner that they would be able to answer questions regarding the text afterwards. No time limit. Half of the subjects read the S-R-text and half the reconstructive.

(2) Free written recall.

(3) The list of propositions was presented and the subjects were asked to indicate their own opinions with regard to the propositions.

(4) The list of propositions was again presented and the subjects were asked to indicate the author's opinions with regard to the propositions.

(5) Second reading of the text.

(6) Estimation of author's opinions with respect to the propositions.

(7) The subjects were asked to write an essay comparing their own ideas on thinking to the writer's and to other possible ideas.

Results

The results to be presented will be based on the following measures.

(1) Truth value of beliefs. This was calculated as the difference between the sum of accepted propositions covering the idea of the text and the sum of accepted propositions not belonging to the text. This choice of measure was made in order to eliminate overall acceptance or rejection response tendencies from the belief measure.

(2) Analytic level of beliefs. This was calculated by taking the absolute difference between the sum of accepted propositions covering the idea of the text and the sum of accepted propositions not belonging to the text's idea.

(3) Truth value of comprehension. This was calculated as the difference between the sum of propositions adequately attributed to the text and the sum of propositions inadequately attributed to the text.

(4) Analytic level of comprehension. This was calculated as the absolute difference between the sum of propositions adequately attributed to the text.

(5) Analytic level of ideas consisting of untested assertions. The sorting data were analyzed in the following way. For each category the number of most frequent propositions (S-R or reconstructive respectively) was calculated. Categories with fewer than three propositions were not included. This number was divided by the total number of propositions in the category. This ratio may be regarded as indicative of the analytic level of each category (with respect to the S-R versus reconstructive distinction). To get an overall measure, the figures were averaged geometrically over categories.

(6) Free recall. The free recall protocols were scored with regard to number of central elements recalled (see Appendix 3). Those cases where misunderstandings or introductions of personal ideas occurred were not scored, neither positively nor negatively.

(7) Free descriptions. The analysis of the free descriptions will not be presented in the present paper as it presented some special problems not covered here.

In Table 2 the raw data showing the sum of accepted propositions of the reconstructive and the S-R-type respectively are shown. From this table the various truth values and analytic levels were calculated

Table 2. Number of accepted propositions of the reconstructive type and the S-R-type respectively.

Text	Subject	Own before RC	Own before SR	Own after RC	Own after SR	Comprehension 1 RC	Comprehension 1 SR	Comprehension 2 RC	Comprehension 2 SR
SR	1	5	7	5	9	5	9	1	7
SR	3	7	5	5	5	8	8	7	8
SR	5	9	11	11	10	10	9	10	9
SR	7	5	6	6	5	7	5	3	7
SR	9	12	9	11	11	11	11	11	10
SR	11	10	5	8	7	6	5	3	7
SR	13	7	10	8	9	3	10	1	11
SR	15	9	7	9	11	7	11	8	11
SR	17	9	6	9	6	7	2	3	6
SR	19	11	9	11	8	11	9	11	10
RC	2	8	9	10	7	4	3	3	4
RC	4	8	4	9	4	10	10	10	5
RC	6	11	9	11	11	12	5	12	5
RC	8	7	3	6	4	3	4	4	1
RC	10	9	5	10	6	9	6	8	3
RC	12	8	1	10	0	12	0	10	0
RC	14	6	8	10	5	6	5	4	1
RC	16	11	11	11	11	11	11	11	11
RC	18	8	6	11	5	9	3	5	1
RC	20	10	10	10	12	10	12	10	12

as presented above. In order to study the sought after effects of truth values and analytic levels and at the same time to isolate other significant covariations, product moment correlations were calculated between all of the measurements mentioned above. These correlations are presented in Table 3. Taking tables 2 and 3 as points of departure, some questions relevant to the proposed way of measuring the effect of world knowledge on comprehension will be posed.

How are belief structure and comprehension related?

The measurements of beliefs before reading are about as highly related to both the first and the second comprehension measure as to the measure of beliefs after reading, as seen in Table 3. The re-

Table 3.

Beliefs before		Comprehension 1		Beliefs after		Comprehension 2		Recall	Sort
truth value	analytic level	truth value	analytic level	truth value	analytic level	truth value	analytic level		
1	2	3	4	5	6	7	8	9	10
1	.343	.590	.467	.699	.579	.577	.611	.030	.181
2		.395	.438	.489	.524	.587	.579	-.142	.320
3			.741	.720	.483	.741	.757	.391	.232
4				.444	.544	.441	.454	-.095	.180
5					.804	.572	.515	.053	.178
6						.441	.454	-.095	.180
7							.955	.095	.372
8								.090	.420
9									.297
10									

lation between comprehension and world knowledge was further studied by calculating the multiple regression coefficients and beta weights for predicting comprehension truth values from the analytic levels and truth values of beliefs. The corresponding figures are found in Table 4.

Table 4. Prediction of comprehension before and after from beliefs before; multiple regression beta weights and correlation coefficients.

	Comprehension 1 Truth value Beta weight	R	Comprehension 2 Truth value Beta weight	R
Beliefs before				
Truth value	.590		.485	
Analytic level	.396		.905	
		.625		.710

The beliefs held by subjects before reading are seen to account for a great deal of the variation in their comprehension. Granted, it could be predicted from the theoretical analysis presented above that comprehension should covary with the measured variations in belief structure, it is astonishing that it did so to such a great extent. The belief measurement was performed one to three weeks before the subjects read the text. During these weeks the subjects would have unlimited chances to change their opinions - perhaps even as a result of the belief measurement. Further, in reading the text, the subjects should have the opportunity of counterbalancing the effect of their own belief structures. This is especially the case when the text is read for the second time. Instead of taking this opportunity, the readers seem to become even more dependent upon their own previous belief

structure in the second reading. Thus a description of the comprehension process cannot be performed solely by analyzing texts and processes. The individual belief structures play an important role in the comprehension process, and cannot be overlooked as is presently the case in a great many of the research approaches to comprehension problems.

The role of hypothetical knowledge

In the theoretical analysis it was suggested that world knowledge should be divided into two parts, one consisting of beliefs, i.e. propositions with truth values attached to them, and one consisting of untested assertions, "hypothetical knowledge". The sorting task was meant to ascertain the analytic level of the untested assertion part as well as of the belief part. The score derived from this task will be high if the subject, in his sorting, differentiates between the two ideas proposed and low if he uses another categorization principle. From Table 3 it is seen that most correlations with this task are low. The task has its highest correlation (.420) with the analytic level of comprehension 2. As is seen from its correlation (.320) with the analytic level of beliefs, the task is not independent of the belief measurement. Furthermore, as the correlation with comprehension is lower for this task than for the belief measurement, it can be inferred that the analytic level of hypothetical knowledge has a very limited influence on comprehension, as compared to that exerted by beliefs.

It might well be that the content of the hypothetical knowledge is related to comprehension though the present investigation could not demonstrate this. The free essays used to get at the content of the subjects' ideas showed that a separation in terms of beliefs and hypothetical knowledge was difficult to make with the essays as points of departure. Perhaps the subjects simply could not discern what they knew about as opposed to what they believed in. The theoretical distinction thus might not have a counterpart as far as the subjects are concerned.

The role of memory

Most research on comprehension has used free recall protocols as the raw data to measure comprehension. This approach was abandoned here. Instead, the free recall protocols were used to give some supplementary information about the processes not covered by the structural descriptions of world knowledge. It was mentioned above that one of the inherent problems of a model which considers comprehension as a matching process is to specify the size of the matching unit. In the present study the propositions presented after reading of the text were to be matched against the text as it was remembered to be. In such a case comprehension would probably be contingent upon memory. A person who recalls more details about the text should also be able to make inferences less influenced by his own world knowledge. It may be supposed that a good comprehension, as measured by the number of appropriate matches, requires a good recall ability. At the same time, a high recall score might be contingent upon a good comprehension. It is thus expected that the recall and comprehension scores should covary to some extent.

It is seen from Table 3 that the recall score is somewhat related

to the comprehension measure, but to a lesser degree than the belief structure is related to comprehension. This result, contrary to expectation, implies that recall and comprehension as measured here are not dependent on each other in any essential respect.

This unexpected finding may be interpreted in different ways. One interpretation may be derived from the methodological difference. As was mentioned above, the recall protocols were scored for degree of reproduction of central elements, which was considered to give as pure a measurement of memory as possible. The comprehension task on the other hand demands memory as well as inferences. Some of the propositions to be matched with the text are direct paraphrases of propositions in the text, others may be inferred from the text, taking two or more propositions as points of departure, and still others may only be inferred from knowledge of the general idea represented in the text (see Appendix 2). It is unlikely that all possible inferences could be obtained from recall protocols alone.

Other interpretations concern the processes resulting in a recall score and a comprehension score respectively. These processes may be analyzed in many different factors and the difference between the processes may be attributed to any of these factors. It has for instance been suggested that persons assigned to learn a text use different levels of processing (Marton, 1975a). Different instructions for study of a given material have also been found to lead to different outcomes in terms of recall of the material (Marton, 1975b).

The present study also showed that the recall score had very low correlations with the subjects' own beliefs before reading (cf. Table 3). This result may be compared to the repeated successes of Bransford and coworkers (Bransford & Franks, 1971; Bransford, Barclay & Franks, 1972) in demonstrating effects of world knowledge on memory, which is also reflected in the later works by Bransford and coworkers (Bransford & Johnson, 1973; Bransford & McCarroll, 1974). The results of the present investigation point to the necessity of separating memory from comprehension in model building and data analyses.

Memory might be regarded as one data basis, supplementing the belief structure in performing the comprehension task. The recall measurement is one of the possible indicators of memory. It can therefore be asked to what extent the variation in comprehension can be accounted for by using recall scores as well as truth values and analytic levels of beliefs as predictors. Table 5 gives the multiple correlation coefficients and the beta weights respectively for the belief structure and recall as predictors of comprehension after the first reading.

The percentage of variance now accounted for is seen to have risen to 56.

Repeated reading and comprehension

As will be remembered from the description of the procedure, subjects were instructed to read the text twice, with measurements of comprehension after each reading. The raw data from these two comprehension measurements are found in Table 3 under the headings

Table 5. Prediction of comprehension 1 from beliefs before and recall. Multiple regression beta weights and correlation coefficient.

	Beta weight	Multiple correlation
Beliefs before		
Truth value	0.644	
Analytic level	0.707	
Recall	0.891	
Joint prediction		0.749

of comprehension 1 and 2 respectively. The interindividual variation as to comprehension was rather constant between the two measurements, as is shown in the product moment correlation between comprehension 1 and 2 of r. 784. In order to see whether the comprehension changed from the first to the second measurement, t-values for correlated data were calculated on comprehension truth values as well as analytic level. The t for the difference between truth values was 2.67 and for the difference between analytic levels 1.77 (comprehension 2 - comprehension 1). It is seen that comprehension improves both in terms of truth values and analytic level, becoming significant on the .01 level and the .05 level, respectively. The S-R-text accounts for most of the increased comprehension.

Discussion

The results presented in the present paper and in a previous one (Waern, 1976) attest to the possibility, and even the necessity of approaching comprehension problems on a more abstract level than has recently been the case. Highly detailed analyses of the human representation in terms of elementary concepts and elementary relations may have no significance in trying to describe what knowledge readers use when trying to arrive at and deal with the idea of a text.

The reader must, of course, be able, from the elementary relations presented in the text, to arrive at a more general description of the idea in the text. This is the parsing problem, which in articicial intelligence research has been approached in different ways. Some workers have incorporated world knowledge in the parsing problem (see e.g., Winograd, 1972), however, world knowledge is still formulated in semantic terms. This might be due to the purpose of their research, i.e. to understand natural language in a world of building blocks with different forms, sizes and colors. In the present situation, where the text refers to abstract rather than psychical concepts, the results suggest that the semantic formulation of world knowledge is subordinated to a formulation in terms of ideas. The suggestion here put forward is that the reader, when reading a certain statement in the text, will attribute it to a certain idea. Which idea he judges the statement to represent depends partly on his own idea structure and partly on the other statements in the text. He will try to make most statements in the text consistent with a single idea which is derived from

the ideas of which he himself can conceive, i.e. from his idea structure. The semantic information of the text will seemingly not be used by the subject unless it discriminates between ideas, or unless the subject has some special reason to attend to semantic features.

The ideas to which the reader will attribute the statements may consist of beliefs as well as of untested assertions. It was an unexpected result that as much as 39-50% of the variation in comprehension between readers could be accounted for by measuring propositions of the belief structure alone. The untested assertion part of the world knowledge seemed to be very slightly related to comprehension. Above, it was suggested that readers do not discriminate between beliefs and untested assertions. A further implication of the present result is that statements in the text which do not conform to the subjects' own beliefs will simply be discarded as the subject has no means by which to represent such statements as hypothetical.

Besides beliefs and hypothetical knowledge, comprehension should be related to the comprehension process itself, which involves i.a. different reading (e.g., skimming versus close reading) and memorization (e.g., rote memorization versus inferences) strategies. Along with the hypothetical knowledge, different motivations and diverse error factors, these strategies will account for only the remaining 50-60% of the variance between individuals. It may be that the best single predictor of comprehension indeed lies in the belief structure.

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(S-R version)

APPENDIX 1

Thinking, Memory and Problem Solving

When solving a problem, the greatest task consists of taking out from the memory that solution which the special problem demands. It is in fact exactly this searching process in the memory which we in everyday terms call "thinking".

The memory can be seen as a storeroom full of the human being's impressions of reality. The impressions can be characterized as sense impressions and action impressions. That which distinguishes a human being's thinking is that the impressions are bound together with each other according to certain principles. Connections between impressions can arise e.g., when two impressions have occurred simultaneously and are retained more easily if this process, simultaneous occurrence, is repeated. The connection between sense impressions and action impression can also be made if a certain action in a certain situation has led to a favorable outcome.

In the process of problem solving, the problem can be seen as a sense impression and the solution to the problem as an action impression. If a person succeeds with a certain manner of solving a prob-

lem, the chance is increased that he will try the same solution the next time he is confronted with a similar problem. If he does not succeed in solving the problem, he is going to have difficulties with similar problems henceforth as well. In short, whether a problem is easy or difficult to solve depends upon whether the person has succeeded in solving similar problems previously. An entirely "new" solution to a problem can only arise by pure chance or by a combination of two or more previous solutions.

Thinking, Memory and Problem Solving (Reconstructive version)

When solving a problem, the greatest task consists of creating something new from the combination of the problem and previous experience. It is in fact exactly this process of creativity which we in everyday terms call "thinking".

Out of what, with what material is the new then created? The material in a solution to a problem consists partly of the person's impression of the given problem, and partly of his previous impressions of the world about him. That which distinguishes a human being's thinking is that the impressions are analyzed as to their most striking characteristics, which makes it possible to arrange the impressions in a meaningful structure. The structure can be formed through classes of impressions which have some (but not all) characteristics in common. It can also be formed through arranging impressions into a ranking centered upon a certain characteristic (e.g., small-large).

In short, the first step in solving a problem is, by an analysis, to sort out the distinguishing characteristics in the problem. This analysis, aided by the analyzing and structuring which the person has made of his previous impressions, provideds raw material for the problem solving. Solving the problem means that the person works with restructuring and changing the characteristics and structure of the material until the problem is solved or is experienced as solved. Regardless of whether the problem has been correctly or incorrectly solved, the process of solving it can lead to a restructuring of the previous experiences in the memory. Every problem-solving process can then be considered as "new" in the sense that an identical structuring of impressions has not been stored previously.

APPENDIX 2

Statements used to measure the reader's own ideas and comprehension

General	S-R	RC
100 It is important that a person receive feedback regarding his solution to a problem	111 It is important that a person get to know whether he has or has not reached the correct solution to a problem	121 It is important that a person receive an opportunity to reflect upon the characteristics of the solution that he has suggested to a problem

General	S-R	RC
	112 A key giving the correct answer is an example of good feedback for the solution of a problem	122 Good feedback for the solution of the problem must be individual: Every person must analyze the solution of the problem according to his own conceptions.
200 After the solution of every problem, the experiences of the solution are incorporated in the memory	211 If one succeeds with a certain problem solution, the chances are increased that he will try the same solution when confronted with a similar problem	222 Every problem solution is arranged in a structure of experiences that may have been modified by the problem solution.
	212 One becomes a better problem solver by succeeding with a problem solution than by failing.	222 One learns as much from a failure to solve a problem as from a success in doing so.
300 In the memory impressions are stored not one by one, but associated with each other in a structure.	311 The memory structure is built up via connections between sense impressions which are strengthened if the action leads to a successful result.	321 That which one remembers is analyzed in terms of characteristics and bound together according to these into meaningful structures.
	312 One can train his thinking by teaching himself to bind together problems with their solutions.	322 One can train his thinking through dividing up problems into smaller components and studying what new structures can be obtained through different alterations and combinations of sub-problems.
400 Thinking is dependent on memory	411 When a problem is to be solved the process is to find the correct solution in the memory to the problem posed. This search through the memory comprises thinking.	421 When a problem is to be solved the process is to construct a new structure partly based upon the characteristics of the problem and partly on the previously structured characteristics in the memory. Thinking consists of this constructive activity.

General	S-R	RC
	412 One can train his thinking by teaching himself different strategies for searching in the memory.	422 Thinking is facilitated by the ability to restructure previous experiences rapidly.
500 Creative thinking cannot emerge from a void, but must always derive from previous experience.	511 Creative thinking emerges either through chance or through a new combination of the impressions stored in the memory.	521 Creative thinking means that the structures stored in the memory are changed, broken down, and reconstructed.
	512 Creative thinking can be promoted by training persons to combine impressions without regard to whether the result is something that actually exists.	522 Creativity can be promoted by training people to analyze their impressions and earlier experiences.
	611 A problem is difficult for a person becaues he has not previously encountered its solution.	621 Different persons have different degrees of difficulty in restructuring their previous experiences so that they fit a given problem.
	612 Children have difficulty solving problems because they have not solved many.	622 Children have difficulty solving problems because they cannot analyze problems nor restructure their experiences in so many different ways.

APPENDIX 3

Central elements in the texts S-R-text

1. Problem solving is related to taking out from the memory
2. Thinking is related to a searching process.
3. Memory is a storeroom full of impressions.
4. Thinking is characterized by connected impressions.
5. Connections can be formed through contiguity, frequency, reinforcement.

6. A problem is related to sense impressions, solution to action impressions.
7. Success increases the probability of the same solution's being used next time. Failure decreases the probability of the same solution's being used next time.
8. New solutions can arise by pure chance or by a combination of previous solutions.

Reconstructive text

1. Problem solving is related to creating something new out of problem and memory.
2. Thinking is related to creating.
3. Materials for creation consist of impressions of problems and reality.
4. Impressions are analyzed as to their distinctive features.
5. Structures can be formed by classifying impressions with common properties or through ranking.
6. Problem solving is related to analysis of distinctive feature.
7. Problem solving is related to structuring of the distinctive features.
8. Each problem solving task is new.